species. In vulnerable subreaches of the San Joaquin River with small, developing populations immediate eradication by be a cost effective strategy (San Joaquin River Riparian Habitat Restoration Program 1998).

CONTAMINANTS

TARGET 1: Reduce losses of fish and wildlife from use of pesticides, hydrocarbons, heavy metals, and other pollutants in the basin (◆◆).

PROGRAMMATIC ACTION 1A: Provide additional funding to enforce State laws regarding point- and nonpoint-source pollution.

PROGRAMMATIC ACTION 1B: Develop a cooperative program to strengthen water quality standards as needed.

PROGRAMMATIC ACTION 1C: Work with local landowners and State and federal agencies to improve land management practices to reduce contaminant input.

PROGRAMMATIC ACTION 1D: Evaluate the use of real-time releases from tile drainage.

TARGET 2: Reduce sediment sources entering the river and bypass system (◆◆).

PROGRAMMATIC ACTION 2A: Conduct an hydraulic analysis of the stability of bypasses.

PROGRAMMATIC ACTION 2B: Cooperatively develop streambed and bank protection and erosion control management alternatives to reduce sources of sediment.

RATIONALE: *Poor water quality resulting from point- and nonpoint-source discharge of toxic chemicals and other pollutants may affect anadromous fish survival in the San Joaquin River basin. Drainage practices in western Merced County result in highly saline and pollution-laden agricultural return flows from Salt and Mud Sloughs into the mainstem San Joaquin River above the confluence with the Merced River. Contaminant input from this area also affects water quality in the downstream Sacramento-San Joaquin Delta Ecological Management Zone.*

Sediment deposition within the mainstem San Joaquin River and its bypasses is a recognized problem. The potential for aggradation of sand in the river bed is a serious constraint to revegetation of riparian habitat in some river segments. Much of the problem sediments appears to originate from erosive processes within the bypasses and some of the eastside tributaries. Therefore the reduction of the sediment problem requires solution of the erosion occurring within the bypasses and eastside tributaries (San Joaquin River Riparian Restoration Program 1998).

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◆ East San Joaquin Basin Ecological Management Zone

Introduction

The East San Joaquin Basin Ecological Management Zone includes the lower Stanislaus, Tuolumne, and Merced rivers. These rivers support Sacramento-San Joaquin Delta health by supplying freshwater inflow, sediments, nutrients, and seasonal habitats for Delta species, especially fall-run chinook salmon, steelhead, waterfowl (including the endangered Aleutian Canada goose), riparian brush rabbit, Swainson's hawk, giant garter snake, and western pond turtle. The overall health of the Delta depends on habitat quality and quantity in this zone and the health of its fish, wildlife, and plant populations.

Important ecological processes that would maintain or increase the health of the East San Joaquin Basin Ecological Management Zone are:

- streamflow,
- stream meander,
- floodplain processes,
- coarse sediment supply including gravel recruitment, transport, and cleansing, and
- water temperature.

Riparian and riverine aquatic is an important habitat within zone and has close links to wetlands areas. Caswell Memorial State Park is the best example of remaining Great Valley riparian habitat in the San Joaquin Valley (with the exception of the Cosumnes River Preserve in the Eastside Delta Tributaries Ecological Management Zone). Seasonally flooded wetlands are common through the lower portions of the basin and are important habitats for waterfowl, shorebird, and wading bird guilds. Important aquatic habitat designations include freshwater fish habitat and essential fish habitat.

Important species include fall-run chinook salmon, steelhead trout, native resident fishes, waterfowl guilds, shorebird and wading bird guilds, and riparian wildlife guilds.

Stressors include:

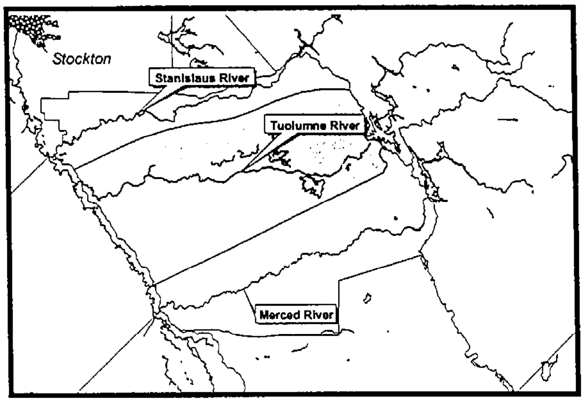
- dams that hinder or block fish migration,
- legal and illegal fish harvest,
- water diversions that result in insufficient flow in the lower portions of most streams,
- high water temperature during salmon and steelhead spawning and rearing,
- poor water quality,
- hatchery stocking of salmon and steelhead,
- gravel mining in the stream channel,
- poor livestock grazing practices,
- high predation levels on juvenile salmon by non-native fish,
- salmon and steelhead harvest,
- and unscreened or poorly screened water diversions.

These stressors have reduced the health of fish wildlife, and plant populations in the zone. Fall-run chinook salmon populations are generally unhealthy because of poor habitat conditions within the zone, entrainment at the Delta pumping plants, and potentially high ocean harvest rates. The status of steelhead in the zone is unknown and will require more focused research to determine specific restoration actions that need to be implemented to improve conditions for its recovery. Wildlife populations are adversely affected by loss of riparian and wetland habitats and the ecological functions that maintain them.

Description of the Management Zone

The East San Joaquin Basin Ecological Management Zone includes the three major eastside tributaries to the San Joaquin River and consists of the following Ecological Management Units:

- Stanislaus River Ecological Management Unit,
- Tuolumne River Ecological Management Unit, and
- Merced River Ecological Management Unit.



Location Map of the East San Joaquin Ecological Management Zone and Unit.

The Stanislaus, Tuolumne, and Merced rivers flow through extensive and biologically valuable grassland/vernal pool complexes located in eastern Stanislaus and Merced counties. Two important National Wildlife Refuges are located in this zone: Merced NWR and San Joaquin NWR. In addition to the larger ecological values, these units also provide habitat for many fish, wildlife, and plant species. They are particularly important as spawning and rearing areas for chinook salmon.

List of Species to Benefit from Restoration Actions in the East San Joaquin Ecological Management Zone

- chinook salmon
- steelhead trout
- giant garter snake
- Swainson's hawk
- greater sandhill crane
- western yellow-billed cuckoo
- riparian brush rabbit
- San Joaquin Valley woodrat
- shorebirds
- wading birds
- waterfowl
- neotropical migratory birds
- native resident fishes
- lamprey
- plants and plant communities.

Description of Ecological Management Units

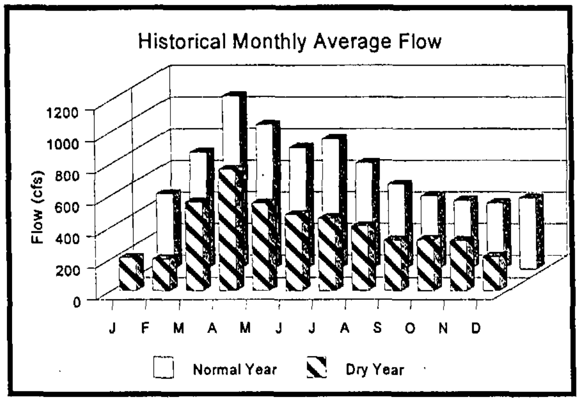
Stanislaus River Ecological Management Unit

The Stanislaus River is the northernmost major tributary in the San Joaquin River basin. The river flows westward into the Central Valley, draining approximately 1,100 square miles in the Sierra Nevada. The average unimpaired runoff in the basin is about 1.2 million acre-feet (af).

Significant changes have been made in the hydrological conditions of the basin since agricultural development began in the 1850s. New Melones Dam, completed by the U.S. Army Corps of Engineers (Corps) in 1978 and approved for filling in 1981, is now the largest storage reservoir in the Stanislaus basin, with a gross capacity of 2.4 million af. The project is operated by the U.S. Bureau of Reclamation (Reclamation) as part of the federal Central Valley Project (CVP). Downstream of the New Melones Dam, Tulloch Reservoir, with a gross storage capacity of 68,400 af, regulates water releases from the New Melones Dam. Goodwin Dam, downstream, regulates releases from Tulloch Reservoir and diverts water for power and irrigation to South San Joaquin Irrigation District and Oakdale Irrigation District.

Monthly unimpaired flows at New Melones (900-square-mile watershed) average approximately 1,600 cubic feet per second (cfs), with highest runoff in the rainfall months of December through March and in the snowmelt months of April, May, and June. This pattern is typical of San Joaquin basin streams originating from the high Sierra. During dry years, inflows are 500 to 1,800 cfs from February through June, whereas summer inflows are less than 50 cfs from August through October. In driest years, inflows are less than 50 cfs from July through February but still reach peaks near 1,500 cfs in April and May. In highest rainfall years, average monthly inflows are 6,000 to 11,000 cfs from February through June, and 600 to 1,400 cfs from August through October.

Monthly historical average flow at Ripon (near the mouth of the Stanislaus River) is approximately 950 cfs and is more uniformly distributed throughout the year than unimpaired flow at New Melones Dam. In dry years, monthly average flows vary between 200 cfs and 500 cfs, except for a small increase to 750 cfs in April. Normal year flows range from 400 cfs to 1,100 cfs, with a peak in April and lowest flows from September through January. In driest years, flows vary from 200 cfs to 400 cfs. In highest precipitation years, flows are similar to unimpaired flows, ranging from monthly averages of 2,000 to 5,000 cfs, with peaks in March and April.



Stanislaus River Streamflow at Ripon (Highway 99), 1981-1991 (Dry year is the 20th percentile year; normal year is the 50th percentile or median year.)

Although considerable flow is diverted for irrigation upstream of Ripon, much of the water released from New Melones is used for water quality control in the San Joaquin River at Vernalis during the irrigation season and is diverted at south Delta pumping plants. Fall minimum flows and spring flow pulses are prescribed to sustain fall-run salmon.

Interim flow releases for fishery purposes in the lower Stanislaus River were designated in a 1987 agreement between Reclamation and the California Department of Fish and Game (DFG). This agreement, enacted under a DFG protest of Reclamation's water right applications to redivert water from New Melones Dam, specified interim annual flow allocations for fisheries between 98,300 af and 302,100 af, depending primarily on the carryover storage at New Melones and inflow. Under the agreement, a 7-year cooperative study program was established to evaluate flows in the lower Stanislaus River.

In addition to flow allocations for fisheries, 70,000 af is a minimum annual allocation for water quality purposes. To meet Delta water quality standards, Reclamation commonly releases additional water over the 70,000-acre-foot requirement. In recent years, coordinating fishery and water quality flow releases and releases for water sales and transfers have resulted in schedules that significantly benefit anadromous fish.

Flows needed for fall-run chinook salmon smolt (the life stage at which salmon are ready for saltwater), emigration, in particular, can be adequately met in drier years with the present annual flow allocations. The results of IFIM and water temperature model for the Stanislaus River indicates that about 99,000 acre-feet can provide suitable conditions between October 16 and June 7 for chinook salmon. There is a positive relationship between spring outflow at Vernalis on the San Joaquin River and at Ripon on the Stanislaus River to the number of adults reaching the river 2½ years later. Smolt survival studies have not been completed for the Stanislaus River and the existing data do not indicate that higher flows would improve smolt survival. Three survival tests have conducted at a range of flow releases between 800 and 1,200 cfs in the Stanislaus River and no obvious relationship between flow and smolt survival resulted from these tests. On the other hand, flow releases made since the 1987 Reclamation and DFG agreement have been substantially greater than those made during the 1967-1991 and yet the chinook salmon population did not rebound.

DFG has developed flow recommendations for the Stanislaus River (California Department of Fish and Game 1993). Recommended flows for the October 1 through March 31 period were based on results of the instream flow study for salmon spawning, egg incubation, and rearing. Flows during April 1 through May 31 for late rearing and smolt emigration were based on results of the smolt survival studies. These flows for the lower Stanislaus River are consistent with spring outflow objectives proposed for the basin at Vernalis on the San Joaquin River. Summer flow recommendations incorporate the needs of oversummering yearling salmon and steelhead. The recommended flows represent the minimum needed for salmon spawning, rearing, and emigration on the lower Stanislaus River. These flows would represent a significant improvement over existing required stream releases but are not optimum flows, particularly in drier water years. The U.S. Fish and Wildlife Service (USFWS 1995) recommended similar flows to double anadromous fish production in the basin.

Water temperature in the Stanislaus River is influenced by ambient air temperatures, late summer storage levels and thermocline development at New Melones Reservoir, the depth of diversions from New Melones Reservoir, and Tulloch Reservoir temperatures and operations.

Fall flow releases to the lower Stanislaus River sometimes exceed critical temperatures for salmon spawning and egg incubation when storage levels at New Melones Reservoir are low. Elevated water temperatures are a problem in critically dry water years, a problem exacerbated by low reservoir storage and the presence of the Old Melones Dam in the reservoir which restricts access to the remaining cold water pool. During the 1987 through 1992 drought, the first fish entering the river to spawn did not arrive until early November, rather than in October, because of low water and high water temperatures. Elevated water temperatures were the major cause of the delay. With such a delay in spawning, juvenile fish are not ready to emigrate until later in spring when high water temperatures again occur in the river and in the mainstem San Joaquin River.

Delayed spawning also reduces survival of eggs in gravel, the number of fry rearing in the river, and the number of young salmon traveling to and through the Delta to San Francisco Bay and the Pacific Ocean. Egg mortality has been shown to increase when temperatures exceed 56°F. When storage levels at New Melones are low, water temperature exceeds 56°F in much of the salmon spawning reach until ambient air temperatures cool the river during November. Water temperatures above 65°F are stressful to juvenile salmon.

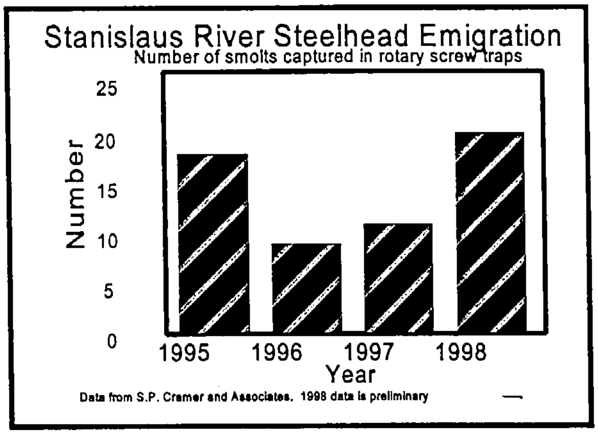
Forty-four small pump diversions have been identified on the lower Stanislaus River, none of which are adequately screened to prevent entrainment (carrying into the diversion) of juvenile salmon and other aquatic organisms. Although losses at these diversions are unknown, the diversions are considered a serious threat to these populations.

Goodwin Dam, located approximately 15 miles downstream of New Melones Dam, is the upstream barrier for steelhead and salmon migration. Spawning occurs in the 23-mile reach downstream of Goodwin Dam (California Department of Fish and Game 1993) and juvenile chinook salmon and steelhead rear in the entire lower river. Historically, the river supported steelhead and spring- and fall-run chinook salmon. The river now supports fall-run chinook salmon and steelhead and perhaps late-fall-run chinook.

Substantial evidence exists to show that there is an extant self-sustaining steelhead run in the Stanislaus River. Since 1995, a small, but consistent, number of juvenile steelhead that exhibit smolt characteristics have been captured in rotary screw traps at two chinook salmon monitoring sites on the lower river (Demko and Cramer 1997; 1998). These fish do not appear to be the result of straying of juvenile hatchery steelhead planted in the Mokelumne River because none of the smolts captured in the screw traps in 1988 were adipose-fin clipped (1997 was the first year of 100% marking of hatchery steelhead at Mokelumne River Hatchery). The presence, over multiple years, of juvenile steelhead that have undergone smoltification and are actively migrating to the ocean is sufficient evidence to conclude that natural production is occurring and a self-sustaining population exists. We note that this is the opinion of the Department of Fish and Game (CDFG 1997) and the Steelhead Project Workteam of the Interagency Ecological Program (IEP Steelhead Project Workteam 1999) as well. Other evidence that a self-sustaining run exists includes:

- CDFG fishery biologists have documented successful reproduction (in the form of juvenile emigrants) in the lower San Joaquin River since 1987 (CDFG 1997).
- Anglers in the Oakdale area report occasional steelhead from 2 to 10 pounds and CDFG creel census information documents the catch of rainbow trout greater than 20 inches (CDFG unpublished data). Examination of scale samples from these larger trout by CDFG biologists show an accelerated growth period typical of estuary or ocean residence (CDFG unpublished data).

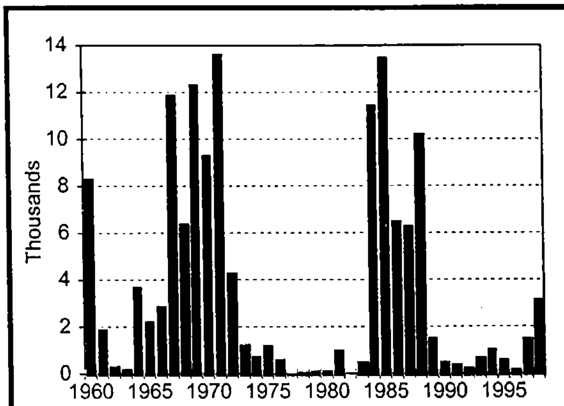
- A 28-inch steelhead illegally harvested from the Stanislaus River was confiscated by CDFG wardens in 1995.



Recent genetic analysis by the National Marine Fisheries Service of Stanislaus River rainbow trout/steelhead collected from the anadromous reach below Goodwin Dam show that this population has close genetic affinities to upper Sacramento River steelhead (NMFS 1997). Further, this Central Valley group forms a genetic group that is distinct from all other samples of steelhead analyzed (132 samples from Washington, Oregon, Idaho, and California) (Busby et al. 1996), hence may be representative of native Central Valley steelhead.

This analysis also provides further evidence that Stanislaus River steelhead are not derived from adults straying from Mokelumne River Hatchery. The analysis showed that steelhead from Nimbus Hatchery on the American River are more closely related to coastal steelhead, which accurately reflects the founding history of Nimbus Hatchery steelhead (Nimbus broodstock was founded from Eel River steelhead eggs). Mokelumne River Hatchery, which rears steelhead from eggs obtained every year from Nimbus Hatchery, is the nearest steelhead hatchery population in proximity to the Stanislaus River, therefore if the Stanislaus River steelhead population is derived from Mokelumne River Hatchery strays, then this population would show close genetic affinities to Nimbus Hatchery steelhead and other coastal steelhead populations.

As in other tributaries in the basin, fall-run chinook spawning escapements (fish that survive migration and spawn) in the lower Stanislaus River have varied considerably since surveys were initiated in 1939. In recent years, spawning escapements have declined to very low levels. In the falls of 1991 and 1992, fewer than 300 salmon returned to spawn in the lower Stanislaus, compared to a recent historic high of 35,000 fish in 1953. Peak runs in the past 30 years have generally followed a series of high rainfall years. Poor runs occur during and following droughts.



Fall-run Chinook Salmon Returns to the Stanislaus River, 1960-1999 (CDFG 1999).

Physical habitat for salmon and steelhead spawning and rearing on the lower Stanislaus River has been lost or degraded because of low instream flow releases. A variety of factors, including low flows, have cumulatively resulted in degradation of spawning gravel, loss of side channels and channel diversity, and reduced spawning gravel recruitment to the active stream channel. Siltation of spawning gravel is primarily caused by watershed disturbance. Existing fine sediments in the lower system may be a result of the intensive hydraulic mining that occurred in the mid-1800s, particularly near the town of Columbia. This problem can best be corrected by minimizing erosion in the watershed and by routinely adding clean gravel to the active channel. The loss of side channels and channel diversity was probably caused by road construction, instream gravel mining, armoring of streambanks by landowners, and by the current practice of removing woody debris from the active channel to protect rafters. Upstream dams and the practice of in-channel gravel mining have removed spawning gravel, altered the migration corridor, and created salmon predator habitat.

Habitat improvement opportunities for chinook salmon in the San Joaquin basin, including the lower Stanislaus River, have been assessed through a DFG-funded study. Projects identified include gravel renovation projects, channel modifications to create new spawning riffles, channel modifications to isolate existing excavated areas from the active river channel to reduce predation and improve the migration corridor, and riparian vegetation restoration.

Recovery options for steelhead in the Stanislaus River have not been assessed, but, as with other regulated rivers in the Central Valley, recovery measures will focus on providing access to historical habitats and/or maintaining adequate water temperatures below dams for oversummer rearing of juveniles. These issues will need to be addressed. The canyon reach between Knights Ferry and Goodwin Dam contains the highest quality habitat for steelhead, and there is a substantial, self-sustaining "wild trout" population in this reach. Juvenile steelhead probably utilize the entire reach between Goodwin Dam and Riverbank for rearing. Water temperatures of 60° F or less should be maintained during the summer months in this reach to provide the necessary conditions for rearing.

The remnant population of riparian brush rabbit is restricted to 198 acres of native riparian forest along the Stanislaus River in Caswell Memorial State Park. A population census following the January 1997 flood indicates that this species is close to extinction.

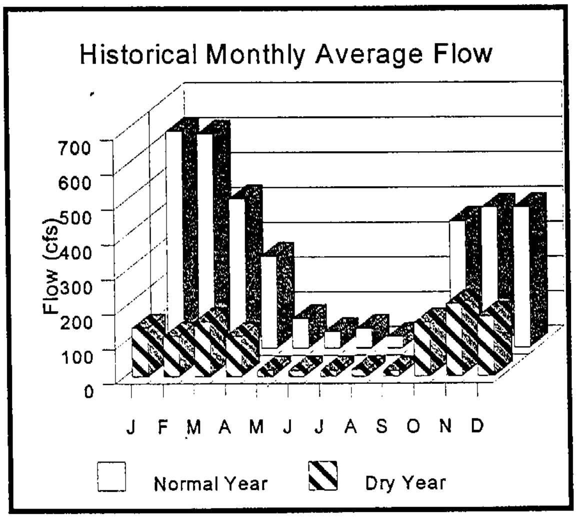
Tuolumne River Ecological Management Unit

The Tuolumne River is the largest tributary in the San Joaquin River basin, with an average annual runoff of 1.95 million af and a drainage area of approximately 1,900 square miles, including the northern half of Yosemite National Park. The lower Tuolumne River below La Grange Dam is divided into two geomorphic zones based largely on channel slope and bedload material (McBain & Trush 1998). The lowermost area, the sand-bedded zone, extends from the mouth upstream for 24 miles. The upper area, the gravel-bedded zone, extends from river miles 24 to 52.

Hetch Hetchy Reservoir (located in Yosemite) was constructed by the City and County of San Francisco in 1923 for drinking water supply, with a capacity of approximately 360,000 af. Cherry Lake (capacity 260,000 af) was completed in 1953 to increase the aqueduct yield to the maximum of approximately 300 cfs (220,000 af per year) currently exported in the Hetch-Hetchy aqueduct to San Francisco. The Modesto and Turlock Irrigation Districts jointly regulate the flow to the lower river from New Don Pedro Reservoir, with a gross storage capacity of 2.03 million af. The reservoir, completed in 1970, provides power, irrigation, and flood control protection. LaGrange Dam, located downstream from New Don Pedro Dam, diverts approximately 900,000 af per year for power, irrigation, and domestic purposes.

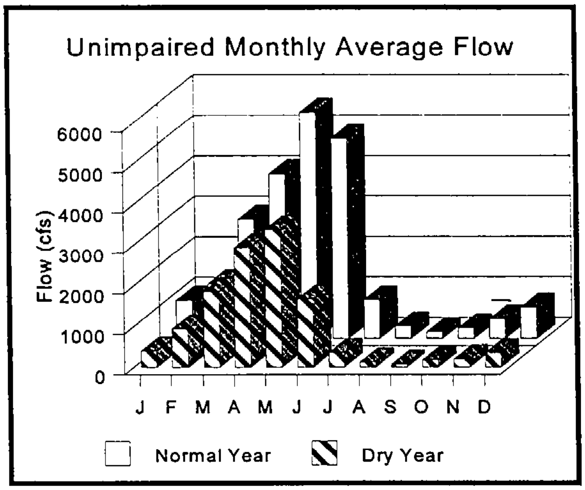
Streamflow in the Tuolumne River is typical of southern Sierra streams originating from the high mountains. Monthly unimpaired flows at New Don Pedro Dam average approximately 2,500 cfs, with peak runoff as snowmelt from April through July. Rainfall can cause substantial runoff from November through March. In highest rainfall years, average monthly inflows range from 10,000 to 18,000 cfs from February through July, 5,000 to 9,000 cfs from November through January, and 1,500 to 3,500 cfs from August through October. In driest years, April and May average monthly inflows peak at only 1,500 cfs, with August through October flows of only 15-30 cfs.

The average historical flow at La Grange near the river mouth is approximately 880 cfs, with most of this flow occurring during winter periods when storms cause reservoir flood control releases in all but low rainfall years. In highest rainfall years, monthly average flows peak in April and May at 8,000 to 10,000 cfs, with summer and fall flows of 900 to 4,000 cfs. Summer flows range from less than 10 cfs



Tuolumne River Streamflow at LaGrange, 1972-1992
(Dry year is the 20th percentile year; normal year is the 50th percentile or median year.)

to 50 cfs in all but wet years. Irrigation return flows along the lower Tuolumne increase summer flows near Modesto to approximately 100 cfs. Flows in dry and normal years generally peak in January to March at 150 to 600 cfs and are minimum in June to September at 10 to 50 cfs.



Tuolumne River Unimpaired Streamflow at Don Pedro Reservoir, 1972-1992 (Dry year is the 20th percentile year; normal year is the 50th or median percentile year.)

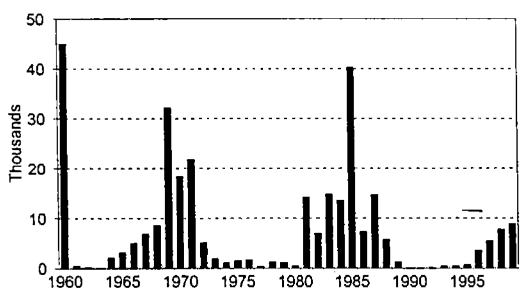
Streamflow strongly influences chinook salmon production in the Tuolumne River. Flow requirements for the lower Tuolumne River are specified in the New Don Pedro Proceeding Settlement Agreement (February 1996) and the Federal Energy Regulatory Commission (FERC) Order Amending License for the New Don Pedro Project (July 1996). USFWS (1995) recommended an alternative flow schedule to achieve the goals of the Anadromous Fish Restoration Program (AFRP).

Low flows can lead to poor water quality, which can delay spawning, decrease egg survival, and cause high juvenile mortality during the spring emigration period. Results of the stream temperature modeling study on the lower Tuolumne River indicate that in recent years, temperature limits for salmon spawning were commonly exceeded in a portion of the spawning reach in October. This contributed to delayed upstream migration and spawning. In recent drought years, the first fish have returned to spawn in the lower Tuolumne River in early November, rather than in October as in previous years, because high water temperatures blocked their upstream migration. As with the other San Joaquin basin tributaries, high water temperatures on the lower Tuolumne River during the spring emigration period may be a significant factor affecting smolt survival. Results of the stream temperature modeling study indicate that in May, and at times in late April, smolts emigrating from the Tuolumne River encounter stressful or lethal water temperatures. Temperature was a consideration in formulating the FERC and AFRP revised flow schedules. However, these new schedules will not ease temperature problems under all ambient conditions, especially in the lower portion of the river during low flows.

LaGrange Dam is the upstream barrier to salmon and steelhead migration. Salmon spawn in the 25-mile reach between LaGrange Dam and the town of Waterford and rear in the entire lower river. Historically, the river supported spring- and fall-run chinook salmon and steelhead trout. A total of 66 adult steelhead was counted at Dennett Dam near the City of Modesto in 1940. Other historical information and the presence of spring-run chinook salmon also provide ample evidence of a steelhead run in the Tuolumne River (Yoshiyama et al. 1996; CDFG 1997)

The river now supports fall-run chinook salmon and steelhead and perhaps late-fall-run chinook salmon. The presence of distinct anadromous runs of late-fall-run chinook salmon is not confirmed. Evidence of natural production (observations of young-of-the-year rainbow trout), creel census information, and anecdotal observations of adult steelhead by anglers, provides some evidence that a steelhead population persists in the Tuolumne River (CDFG 1997). Because there has been no focused effort to assess the steelhead population in the Tuolumne River, and there is essentially no indirect or bycatch information from other monitoring programs on which to estimate a probability of extinction, there is no information available to conclude that steelhead are extirpated from the Tuolumne River. This fact, and the anecdotal information and observations cited above, have led CDFG to conclude that a remnant steelhead population still exists in the Tuolumne River (CDFG 1997).

As in the other basin tributaries, fall-run spawning escapements in the lower Tuolumne River have varied substantially. Population fluctuations are the result of extreme variations in environmental conditions in the river, Bay-Delta, and ocean. Since surveys were initiated, the Tuolumne River, on average, has supported the highest spawning escapements (fish that survive migration and spawn) among the San Joaquin basin tributaries. During the 1987 through 1992 drought, chinook salmon spawning runs in the lower Tuolumne River declined drastically. In the falls of 1991 and 1992, fewer than 300 adults returned to spawn, as compared to a recent peak of 40,000 in 1985 and an earlier estimate of 130,000 in 1944.



Fall-run Chinook Salmon Returns to the Tuolumne River, 1960-1999 (CDFG 1999).

The San Joaquin NWR (780 acres) is located at the confluence of the San Joaquin and Tuolumne rivers. This refuge provides important riparian and seasonal wetland habitats for Aleutian Canada goose, greater sandhill crane, western yellow-billed cuckoo, waterfowl, shorebirds, and neotropical migrant birds.

Chinook salmon smolt survival studies completed thus far on the lower Tuolumne River indicate that adequate spring flows improve smolt survival. Smolt appears to be the critical bottleneck in the life cycle, because smolt production determines adult run size. Unnaturally high summer flows in the salmon spawning and rearing areas below the dams from storage releases for irrigation sustains large populations of predatory fish. These predators are then present in other months and can cause significant young salmon losses.

Steelhead and chinook salmon spawning and rearing habitat has been degraded because of low instream flow releases, which resulted in siltation of spawning gravel, and lack of spawning gravel recruitment. EA Engineering (1992) examined the distribution and abundance of chinook spawning habitat and concluded that spawning habitat was a significant factor limiting salmon production in the Tuolumne River. In addition, the study suggested that lack of gravel supply, combined with Tuolumne fall-run chinook's preference to spawn in the upper reach, led to substantial superimposition of redds, with this being a major cause of chinook mortality.

In major portions of the spawning reach and below, riparian vegetation has been removed because of agricultural development, cattle grazing, urban development, and gravel mining. Gravel mining in the active stream channel has removed gravel from long stretches of the spawning reach. In roughly half of the spawning reach, extensive mining has left long, deep pools and a widened channel. These pools provide habitat for salmon predators, such as largemouth and smallmouth bass, and contribute to warming the river. The 1992 EA Engineering study also revealed that these introduced bass species may be a dominant cause of juvenile chinook mortality, especially under low flow conditions in the Tuolumne River. The highest densities of predatory fish were observed in former in-channel gravel extraction pits.

Thirty-six small irrigation pump diversions have been identified on the lower Tuolumne River; none are screened. Juvenile salmon losses at these sites are unknown, but cumulatively, they may cause a measurable loss of young salmon and steelhead.

Illegal harvest of upstream migrating chinook salmon has been identified as a factor limiting production in the basin. With many miles of migratory habitat that are often under low-flow conditions, salmon are particularly vulnerable to poaching.

Steelhead recovery options for the Tuolumne River have not been addressed by the management agencies. However, the ESA listing of steelhead populations in the San Joaquin tributaries will necessitate that options be identified and implemented. As with other regulated rivers in the Central Valley, recovery measures will need to focus on providing access to historical habitats and/or maintaining adequate water temperatures below dams for oversummer rearing of juveniles. These issues will need to be addressed in future recovery planning.

MERCED RIVER ECOLOGICAL MANAGEMENT UNIT

The Merced River is the southernmost stream used by chinook salmon in the San Joaquin River basin and in California. The river flows westward into the valley, draining approximately 1,275 square miles in the Sierra Nevada mountains and foothills, including the